



Philosophical Transactions

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If these Observations receive the Countenance of this Learned *Society*, I shall think myself sufficiently recompensed; and am,

Gentlemen, with the highest Esteem,

Your most obedient humble Servant,

W. Watfon.

V. *A Sequel to the Experiments and Observations tending to illustrate the Nature and Properties of Electricity; in a Letter to the Royal Society from the same.*

Gentlemen,

Read Oct. 30. 1746. I. **T**HE favourable Reception wherewith you honour'd some Papers I laid before you some time since, relating to Electricity, emboldens me to trouble you again upon the same Subject: And I am the more encouraged so to do, as the Progress of our Discoveries therein, both here and abroad, has been so rapid; that what, little more than a Year ago, we conceived to be the *ne plus ultra* of our Inquiries, is now regarded as mere Rudiments.

2. It were trespassing too much upon you, to recount the great Number of Experiments I have made; for which Reason I shall only take notice of such as are either in themselves striking, or tend to illustrate some Proposition.

3. At the Beginning of last Summer I caused a Machine to be made for electrical Purposes; the Wheel whereof was four Feet in Diameter. In the Periphery of this Wheel were cut four Grooves, corresponding with four Globes of ten Inches Diameter, which were disposed vertically at about three Inches Distance from each other. One, two, or the whole Number of these Globes might be used at Pleasure. They were mounted upon Spindles of two Inches Diameter, and their mean Motion round their Axis was about eleven hundred times in a Minute. As it is next to impossible to have these Globes blown and mounted perfectly true, I order'd the Leather Cushions, with which they were rubb'd, to be stuffed with an elastic Substance (curled Hair) that the Globes in their Rotations might be as equally rubb'd as possible. You might likewise cause the Globes to be rubb'd by the Hands of your Assistants; but under a certain Treatment (of which hereafter) the Cushions excite equally strong. The Leather Cushions were now-and-then rubb'd over with Whiting. As a minute Detail of the Parts of this Machine would take up too much of your Time, I have herewith laid before you a Draught thereof.

4. I lined one of these Globes to a considerable Thickness, with a Mixture of Wax and Resin, in order to observe whether or no the Electricity would be the sooner or more strongly excited; but I found no Difference in the Power of this Globe from the others, which were without this Treatment.

5. The Power of Electricity is increased by the Number and Size of the Globes to a certain Degree;

Y y y 2

but

but by no means in proportion to their Number and Size: Therefore, as the Bodies to be electrified will contain only a certain Quantity of Electricity, of which more largely hereafter; when that Quantity is acquired, which is soonest done by a Number of Globes, the Surcharge is dissipated as fast as it is excited.

6. After the Globes had been a few times used, I found myself Master of a much greater Quantity of electrical Power, with much less Labour to myself, than when I used only Tubes. I could attract and repel light Substances at a much greater Distance than before; fire Spirits of Wine, Camphire, and all other Substances whose Vapours were inflammable, with great Ease, and at any Distance, with Non-electrics placed upon Originally-electrics: I could fire them, I say, at all times; though not equally easy, when the Weather was moist.

7. I discover'd with this Machine, and communicated to several Members of this *Society*, several of the Experiments said to be first made by M. *le Monnier* at *Paris*, before the Letter communicating them was received by our most worthy *President* from thence.

8. I order'd another Machine to be made for a Friend of mine, which carried a Globe of sixteen Inches Diameter. I united the Power of this large Globe with that of three of the others before-mention'd, and found the Strokes from the excited Non-electrics not increased according to my Expectation. In two Experiments indeed, where the Dissipation of the whole Power of these Globes was visible as fast as it was excited, the Effect of this
additional

additional Globe was very considerable. The first was, when two Pewter Plates were held, one in the Hand of an electrified Man, and the other by one standing upon the Floor: When these Plates were brought near each other, the Flashes of perfectly pure and bright Flame were so large, and succeeded each other so fast, that, when the Room was dark-en'd, I could distinctly see the Faces of thirteen People, who stood round the Room. The other was from a Piece of large blunt Wire hanging to the Gun-barrel; from the End of which, when electrified, and any black * Non-electric unexcited was brought near, though not near enough to cause a Snap, a Brush of blue lambent Flame, totally different from the former, was very conspicuous when the Room was dark, of more than an Inch long and an Inch thick. I mention that what is held near the Bottom of the Wire should be black, because then you see this Flame more sharp. Here the phosphoreal Smell might be perceived at a considerable Distance. If the Back of your Hand was brought so near this Wire as to occasion a Snap, and these Snaps were received for some time, you would feel them

* In the Course of these Observations, whenever I mention either Originally-electrics or Non-electrics, I always understand the whole *Genus* of each. Thus when I mention a Man placed upon Originally-electrics, I am indifferent whether he is suspended either in Lines of dry Silk, Hair, or Wool; or (which is much more convenient) if he stands upon Glass, Wax, Resin, Pitch, Sulphur, &c. or upon different Mixtures of these, if of a sufficient Thickness. As we are now Masters of a greater electrical Power than heretofore, I have found the Electricity pervade, tho' in very small Quantity, Originally-electrics of above four Inches Diameter.

them like so many Punctures upon your Skin, occasioning red Spots, which have lasted four and twenty Hours.

9. If, when a Person is electrified, he brings his Hand upon the Cloaths of one that is not, they both have a Sensation exactly resembling that of many Pins running into the Skin, which continues as long as the Globes are in Motion. This is most perceptible when the Cloaths are of thin woollen Cloth or Silk, animal Substances; less so, when of Linen or Cotton, which are vegetable.

10. If some Oil of Turpentine is set on fire in any Vessel held in the Hand of an electrified Man, the thick Smoke that arises therefrom receiv'd against any Non-electric of a large Surface, held in the Hand of a second Man standing upon an electrical Cake; this Smoke, I say, at a Foot Distance from the Flame, will carry with it a sufficient Quantity of Electricity for the second Man to fire any inflammable Vapour. The electrical Strokes have been likewise perceptible upon the touching the second Man, when the Non-electric held in his Hand has been in the Smoke of the Oil of Turpentine between seven and eight Feet above the Flame. Here we find the Smoke of an Originally-electric a Conductor of Electricity.

11. Likewise if burning Spirit of Wine be substituted in the Place of Oil of Turpentine, and if the End of an iron Rod in the Hand of the second Man be held at the Top of the Flame, this second Man will kindle other warm Spirits held near his Finger. Here we find that Flame conducts the Electricity, and does not perceptibly diminish its Force.

12. These two Experiments demonstrate, that the Opinion of those is erroneous, who suppose the electrical *Effluvia* to be of a sulphureous Nature; and that these themselves are set on fire at the Snapping observ'd, when you bring Non-electrics unexcited to those that are. If their Opinions were true, the electrical *Effluvia* should be destroyed by the Flame in both the preceding Experiments; the contrary of which is observed.

13. I now proceed to take notice of that surprising Effect, that extraordinary Accumulation of the electrical Power in a Phial of Water, first discover'd by Professor *Muschenbroek*, a Man born to penetrate into the deepest Mysteries of Philosophy: And I hope I shall stand excused, if I enter into a minute Detail of the Circumstances relating thereto. The Experiment is, that a Phial of Water is suspended to a Gun-barrel by a Wire let down a few Inches into the Water through the Cork; and this Gun-barrel, suspended in silk Lines, is applied so near an excited glass Globe, that some metallic Fringes inserted into the Gun-barrel touch the Globe in Motion. Under these Circumstances a Man grasps the Phial with one Hand, and touches the Gun-barrel with a Finger of the other. Upon which he receives a violent Shock through both his Arms, especially at his Elbows and Wrists, and across his Breast. This Experiment succeeds best, *ceteris paribus*,

1. When the Air is dry.
2. When the Phial containing the Water is of the thinnest Glass.

3. When the Outside of the Phial is perfectly dry.
4. In proportion to the Number of Points of non-electric Contact. Thus if you hold the Phial only with your Thumb and Finger, the Snap is small ; larger when you apply another Finger, and increases in proportion to the Grasp of your whole Hand.
5. When the Water in the Phial is heated ; which being then warmer than the circumambient Air, may not occasion the condensing the floating Vapour therein upon the Surface of the Glafs.

14. From these Considerations it is to be observ'd, that this Effect arises from electrifying the non-electric Water, included in the originally-electric Glafs ; so that whatever tends to make the Outside of the Glafs non-electric by wetting it, as, a moist Hand, damp Air, or the Water from the Inside of the Phial, defeats the Experiment, by preventing the requisite Accumulation of the electrical Power.

15. That a Gun-barrel is absolutely necessary to make this Experiment succeed, is imaginary ; a solid Piece of Metal of any Form is equally useful. Nor have I yet found, that the Stroke is in proportion to the Quantity of electrified Matter ; having observed the Stroke from a Sword as violent as that from a Gun-barrel with several excited iron Bars * in Contact with it.

16.

* If of six Men touching each other, and standing upon Originally-electrics, one touches the Gun-barrel, the whole are electrified ; all these then must be consider'd, as so much excited non-electric Matter. From the Aggregate of all these, not more Fire is visible upon the Touch than from either of them singly,

16. I have tried the Effect of increasing the Quantity of Water in the Glasses of different Sizes, as high four Gallons, without in the least increasing the Stroke. If * Filings of Iron are substituted in the Room of Water, the Effect is considerably lessen'd. If Mercury, much the same as Water; the Stroke is by no means increased in proportion to their specific Gravities, as might have been imagined §.

17. The Phial should not be less than can conveniently be grasped. I generally make use of those, which hold seven or eight Ounces, and fill them about four Fifths with Water; and the Stroke from one of these, under the same Circumstances, is equally strong with that of a *Florence* Flask held in the Hand, which I have sometimes made use of; though the Glas of this last is equally thin with that of the Phial, and the Quantity of Water four times as much. That the Stroke therefore is not as the Quantity of Water electrified, is evident from this Experiment. This Fact does not depend upon my Judgment alone, but likewise upon the Opinions of several learned Members of this *Society*, who have experienced the greater and less Quantity of Water.

18. If a dry Twig of Birch, or any other Wood, be run through the Cork instead of the metallic Wire,

* For a further Account of the Filings of Iron, made use of in this Experiment, see *these Transactions*, Vol. XLV. p. 107,

§ In this Experiment, and in others, wherein we assert, that the Stroke is not increased in proportion to the Quantity of electrified Matter; it must always be understood, that the excited Non-electrics themselves are touched, without being contained in Originally-electrics, as Water in the Glas; for otherwise (as will hereafter be specified) the Effects of different Quantities of Matter will be very different.

Wire, the Stroke is not greater than is usually felt from the Gun-barrel without the Application of the Water. The Stroke is likewise lessen'd, if the Phial is held in the Hand with a Glove on.

19. After the Gun-barrel and Phial have been sufficiently excited, which is done in a few Seconds, the Surcharge is dissipated; so that the continuing the Motion of the Machine ever so long after the Saturation is complete, does not increase the electrical Force.

20. The Force of the Stroke from the electrified Phial does not increase in proportion to the Dimensions of the Glass, or the Number of Globes employed. I have been struck as forcibly with one Phial from a Globe of seven Inches Diameter, as when I made use of, at the same time, one of sixteen Inches, and three of ten. I have been lately informed, that at *Hamburg* a Sphere was employed for this Purpose a *Flemish* Ell in Diameter, without the expected Increase of Power.

21. When the Phial is well electrified, and you apply your Hand thereto, you see the Fire flashes from the Outside of the Glass wherever you touch it, and crackles in your Hand.

22. The Phial may be electrified by applying the Wire therein to the Globe in Motion; after which, if it is grasped in one Hand, and the Wire touched with a Finger of the other, the Stroke is as great as from the Gun-barrel. If you only bring your Finger near the End of the Wire without touching it, you observe the same Brush of blue Flame, as from the Wire hanging to the Gun-barrel, before taken notice of. This instantly disappears upon touching

touching the Wire, though you do not receive a Shock, unless at the same time you grasp the Phial.

23. If you grasp the Phial with your Hand, and do not at the same time touch the Wire, the acquired Electricity of the Water is not diminished. So that, unless by Accident or otherwise the Wire is touched, the electrified Water will contain its Force many Hours, may be convey'd several Miles, and afterwards exert its Force upon touching the Wire.

24. If, when the Machine is in Motion, the Phial is hung upon the Gun-barrel, no Increase of the Stroke is perceived upon touching the Gun-barrel with your Finger, unless at the same time the Phial is taken in the Hand.

25. If, when the Gun-barrel and Phial are excited, you grasp the Phial with one Hand, and touch the Gun-barrel with a Piece of any Metal held in the other, the Shock is as great in your Arms as though you touched the Gun-barrel with your Finger; but not the least Shock is felt, if, instead of Metal, you touch the Gun-barrel with a Piece of dry Wood.

26. I have felt a very great Stroke, when I hung two Phials to the Gun-barrel, and, grasping them both, brought my Forehead near it. The Shock then was so violent, that I seem'd stunn'd, as though struck on the Head with a great Stick, and I have never since chose to repeat this Experiment. This Increase of the electrical Force was owing to the additional Phial, whereby the Points of non-electric Contact were augmented.

27. Likewise if a Person placed upon Originally-electrics, grasps two Phials, as before-mention'd, and a second Person, standing upon the Floor, touches any Part of his Body, a very slight Stroke only is perceived. But if the second Person, while the Globes are in Motion, places one of his Fingers upon the Hand, or any Part of the naked Body of the first, and at the same time touches the Gun-barrel with his other Hand; both feel a Shock equal to that just now mention'd, but more tolerable, because not felt in the Head, in the Arms only, and across the Breast. In this Experiment, it is not necessary that the Outside of the Glasses held in the Hands should be dry, as in the former Experiments; because whatever by the Moisture is communicated to the Man, is stopped by the Originally-electrics upon which he is placed. If, instead of his Hand, you gently touch the first Person's Cloaths, you only perceive a small Stroke upon your Finger; but if you press his Cloaths close to his Body, you frequently perceive a double Stroke; the one, slight from his Cloaths; the second, a violent Shock from his Body.

28. Upon shewing some Experiments to Dr. *Bevis*, to prove my Assertion that the Stroke was, *cæteris paribus*, as the Points of Contact of Non-electrics to the Glass, that ingenious Gentleman has very clearly demonstrated it likewise by the following Experiment: He wrapped up two large round-bellied Phials in very thin Lead so close as to touch the Glasses every-where, except their Necks. These were filled with Water, and cork'd, with a Staple of small Wire running through each Cork into the
Water.

Water. A Piece of strong Wire about 5 Inches long, with an Eye at each End, was provided, and at each End of this hung one of the Phials of Water by the small Staple running through the Cork. A small Wire Loop then was fasten'd into the Lead at the Bottom of each Phial, and into these Loops was inserted a Piece of strong Wire like the former. If then these Phials were hung across the Gun-barrel and electrified, and a Person standing upon the Floor touched the bottom Wire with one Hand, and the Gun-barrel with the other, he received a most violent Shock through both his Arms, and across his Breast.

29. These Phials may be concealed, and the Shock be more universal, in the following manner: The Phials may be placed in a Corner of the Room, and any thing laid over them, so as not to touch the upper Wires; then a very fine Wire must be suspended to the Gun-barrel, and fasten'd to the upper strong Wire. A second Piece of small Wire, of a sufficient Length to reach from the Phials almost under the Gun-barrel, must be fastened to the lower strong Wire, and this may be conceal'd under a Floor-cloth. The Phials then are electrified; and if a Person, placing his Foot upon the Floor-cloth over the Wire which comes from the Bottom of the Phials, touches the Gun-barrel, he receives a most terrible Shock. The first time I experienced it, was when the Phials were fully electrified, and both my Feet were placed upon the Wire. Upon receiving the Stroke from the Gun-barrel upon my Finger, it seemed to me, used as I am to these Trials, as though my Arm were struck off at my
Shoulder,

Shoulder, Elbow, and Wrist; and both my Legs, at the Knees, and behind near the Ankles. So that, to try the Effects of this Experiment, you must be careful of not electrifying the Phials too much. If a dozen or more of these Phials, or one very large Bottle, were cover'd over with thin Lead in the above manner, and strongly electrified, and this Electricity were discharged by a Man at once in the manner here mention'd, I should dread the Consequences.

30. We must observe, that this Shock is not felt, unless the Wire, coming from the Bottoms of the Bottles, is touched; and then not, if the Shoes are dry, and of consequence originally-electric. In this Experiment we see the Effects of the Increase of the Points of Contact; and it seems the more surprising to those who are not acquainted with the Cause, when the Wire is concealed under a Floor-cloth, that the moving of their Feet only one Inch, should occasion them, all other Circumstances apparently the same, to feel a violent Shock, or none at all. A thick Carpet, instead of a Floor-cloth, is liable to prevent the Success of this Experiment, for the same Reason as dry Shoes. This Experiment may aptly enough be called, the springing an electrical Mine.

31. If, in the former Experiment, the lower small Wire is fasten'd to an iron Rod; and if, when the Phials are ever so strongly excited, that Rod is held in the Hand of a Man standing upon the Floor, and with it he touches the Gun barrel, he perceives no Shock, for Reasons presently to be assigned. But if he takes this iron Rod in one Hand, and touches the Gun-barrel with the other, he then is violently
struck,

struck. We must here observe, that the Violence of the Stroke is always felt in our Bodies, in proportion to the Loudness of the Explosion, and the Quantity of Fire seen. Therefore, as both these are equally perceptible, whether the Electricity passes only thro' the Iron, as in the first of these Instances, or thro' our Bodies equally with the Iron, as in the second; we conclude, that in both there is in the same Degree of electrical Force. By the first of these Methods you are capable of making others sensible of the electrical Force, without feeling it yourself. This Experiment, as well as the last, will admit of infinite Variation.

32. If a Man, standing upon an electrical Cake, takes the Phial suspended to the Gun-barrel in his Hand, by these means he acquires some electrical Power; for if, under these Circumstances, he touches the Gun-barrel, he only receives a slight Stroke. If then, without having had any Communication with unexcited Non-electrics, he touches the Gun-barrel again, the Globes being yet in Motion, he receives no Stroke at all.

33. If to the Gun-barrel an Egg, either raw or boiled, is suspended by a Piece of Wire, and a Person, grasping the electrified Phial in one Hand, brings the Palm of his other near the Bottom of the Egg; at that Instant he receives a smart Stroke, and his Hand seems full of a more red Fire than is usually observed. In this Experiment the Stroke is more confined to the Hand without shocking the Arms, than when you touch the Gun-barrel itself; it more resembles a Stroke over the Hand with a *Ferula*.

34. If any Number of People stand upon Originally-electrics, and communicate with each other by any non-electric Medium, especially Metal, they are by these means all equally electrified; and if a Person standing upon the Floor, and holding the Phial of Water hanging to the Gun-barrel in his Hand, touches the Person furthest from the Gun-barrel, the whole Number receives a Shock equal to any one touching the Gun-barrel singly.

35. If a Number of Persons, how great soever, stand upon the Ground, communicating with each other as before, the first of which grasps the Phial, and the last touches the Gun-barrel, the whole Number receive a Shock like the former. This, we are inform'd, M. *le Monnier* at *Paris* communicated through a Line of Men; and other Non-electrics, measuring nine hundred Toises.

36. Several Experiments shew, that the electrical Force always describes a Circuit; *e. g.* if a Man holds the electrified Phial in one Hand, and touches the Gun-barrel with the other, he feels the Shock in no other Parts of his Body than in his Arms, and across his Breast. So that here we see the electrical Power darts *rectissimo cursu* between the Gun-barrel and Phial. This is more particularly demonstrated by the following Experiment, in which, though the two Lines of Persons may be of any Length, we only specify, that each consists of four, for the sake of Perspicuity.

37. Of one Line, let *A* (*see* TAB. III.) touch the Gun-barrel, standing upon Wax, and communicate with *BCD* likewise standing upon Wax. Of the other Line, let *x* take the electrified Phial in his
Hand,

Hand and join with 2, 3, and 4, all standing upon the Floor. If, under these Circumstances, the first Line is electrified, and 4 touches *D*, all eight are struck through. If 4 touches *C*, *D*, though electrified, feels nothing, and the remaining seven are struck; so that here *D* is left out of the Circuit. If 4 touches *B*, only six feel the Shock, and *C* and *D* feel nothing; and thus you may proceed to *A*, who must always necessarily feel, if either himself or any of his Line is touched. If, when both Lines are as before-mention'd, *D* touches 3, 4 is left out of the Circuit, and the remaining seven feel the Stroke. If *C* touches 2, the Circuit consists of five, *D*, 3, and 4 being, though under the same Circumstances, left out: Always observing, however these Circuits are diversified, that *A*, who touches the Gun-barrel, and 1, who holds the Phial, are certain to feel the Stroke.

38. This Experiment may be reversed, the Lines being as before, in the following manner, wherein likewise this Circuit is always observable. Let *A* (see TAB. III.) touch the Gun-barrel as before, and *D* hold the Wire of the electrified Phial in his Finger. Let 4 grasp the Phial, and 1 touch *B*; then *A* feels nothing, being left out of the Circuit, and the other seven are struck. If 4 touches *C*, then *A* and *B* feel nothing, the Circuit consisting of the remaining six. But it is to be observed, as in the former Experiment, that 4, who grasps the Phial, and *D*, who holds the Wire, must of Necessity be always in the Circuit. I have been the more particular in this Matter, as it demonstrates the Course of

the electrical Power to be in the most direct manner between the Gun-barrel and the electrified Phial.

39. Likewise, if a Person, standing upon an Originally-electric, touches the Gun-barrel with his right Hand, a Piece of Wire being placed round his left Leg, and a second Person, standing likewise upon the Wax, takes hold of the Extremity of this Wire; then let another Person, standing upon the Floor, and grasping the electrified Phial, touch any Part of the second Person's Body. Upon this Touch, the second Person is shook as usual; but the first feels the Stroke only in his left Leg and right Arm, the nearest Course of the electrical Power.

40. If any Number of Persons communicate by Pieces of Wire, and if any one of them brings together the Ends of the two Pieces of Wire in his Hands, upon the Gun-barrel's being touch'd, he will perceive no Stroke. But if the Ends of the Wires are but a Quarter of an Inch asunder, he will be shook in both his Arms; because then his Body will become Part of the Circuit.

41. If, when any Number of Persons join Hands, or communicate by any metallic Medium standing on the Floor, one grasps the Phial, and joins with the rest; upon the Gun-barrel's being touch'd by the last Person of the Line, the whole Number are struck, and he who grasps the Phial, as forcibly as the rest. But if two Phials are employed, and he grasps them both, with a Piece of Wire of sufficient Length held between his Fingers, which Wire touches both Phials, and its End is taken hold of by the second Person of the Line; if then the last Person touches the excited Gun-barrel, all in the
Line

Line are violently struck, except the Person who grasps the Phials ; but he feels little or nothing of the Stroke.

42. The Stroke is very violent, when a Wire is put round the naked Head, or under the Peruke, and the Person grasping the Phial touches the Gun-barrel with the Ends of the Wire, or if he holds the Wire between his Teeth.

43. If a Person, standing on the electrical Cakes with Gold or Silver Lace upon his Coat, takes hold of the Gun-barrel, and another Person grasping the electrified Phial touches the Bottom of the Lace, the Person electrified, if he holds down his Head, feels the Blow under his Chin. The Lace in this Instance has the same Effects as a Piece of Metal ; at the End of which, if placed in the same manner, you would necessarily feel the Stroke.

44. I now proceed to shew, by what Steps, in my Inquiries into the Nature of Electricity, I discover'd that the glass Tubes and Globes had not the electrical Power in themselves, but only served as the first Movers and Determiners of that Power.

45. Several Months since, I observ'd that, by rubbing a glass Tube, while standing upon a Cake of Wax, in order, as I expected, to prevent any of the electrical Power from discharging itself through me into the Floor ; contrary to my Expectation, that Power was so much lessen'd, that no Snapping was to be observ'd upon another's touching any Part of my Body. But if a Person not electrified held his Hand near the Tube whilst it was rubbing, the Snapping was very sensible. This I shew'd to several Members of the *Royal Society*,

and others, who did me the Honour to visit me. Afterwards I met with an Experiment of the same kind, in a Treatise publish'd by Professor *Bose*, intitled, *Recherches sur la cause et sur la veritable theorie de l'Electricité*, which that ingenious Gentleman says, had given him great Trouble by its Oddness. The Experiment is, that, if the electrical Machine is placed upon Originally-electrics, the Man who rubs the Globes with his Hands, even under these apparently favourable Circumstances, gives no Sign of being electrified, when touched by an unexcited Non-electric. But if another Person, standing upon the Floor, does but touch the Globe in Motion with the End of one of his Fingers, or any other Non-electric, the Person rubbing is instantly electrified, and that very strongly. The Solution of this *Phænomenon*, seemingly contrary to the already discover'd Laws of Electricity, had terribly tormented him; but however he has given us the following, which he modestly calls a plausible Subterfuge rather than a Solution; *viz.* that a Power cannot act at the same time with all its Vigour, when one Part of it is already employed; as a Horse, who already draws an hundred Pounds, cannot draw an additional Weight as freely as if he had not been loaded at all. That the Hand excites the Virtue already in the Sphere; therefore if the same Power impregnates the Man, there remains none for the Globe. That the Virtue of the Globe then cannot be communicated at the same time to the Man, by whom it is created. That he, who gives it, cannot receive it himself. From these, and such-like Considerations, it appears to him,

him, that the Man upon the Ground, who holds his Fingers to the Globe in Motion, instead of his diminishing its electrical Force, throws that Force back again over the Man, who excited it. That the Finger in this Case seems to operate as an Electric *per se*, and drives back the electrical Power.

46. I have seen an Account of * Mr. *Allamand*, lately printed at the *Hague*; wherein he takes notice of this *Phænomenon*. He tells us, that as Part of the electrical Power of the Globe passes off by the Frame, upon which the Globes are mounted, into the Floor, and dissipated thereby; he conceived, that if the Machine, and the Man who rubb'd the Globe, were placed upon Pitch, to prevent this Dissipation, the Fire of Electricity would be more strong. But the Consequence is extremely odd and unexpected; for the contrary happens; and the electrical Power is considerably diminished, and sometimes there is even none at all.

47. I tried this Experiment several times with my Machine, and the Man, who turns the Wheel thereof, mounted upon the electrical Cakes. If the Air was dry, and the Machine placed at some Distance from non-electrical Substances, as the Sides of the Room, Chairs, and such-like; after one or two small Snaps, the Gun-barrel, supported by silk Lines, and hanging in Contact with the Globes, would, tho' the Machine were in Motion a considerable time,
attract

* *Bibliothèque Britannique pour les Mois de Janvier, Février, et Mars, 1747.*

attract no light Substances, nor emit any Fire. This induced me to conceive, that the electrical Power was not inherent in the Glass, but came from the Floor of the Room; and if the Fact were so, the Gun-barrel should snap upon my touching any Part of the Machine. The Consequence fully answer'd my Conjectures; for while I stood upon the Floor, the Globes still in Motion, I put one Hand upon the Frame of the Machine, and touched the Gun-barrel with one of the Fingers of my other. Upon this, Fire issued, and the Snapping continued as long as I held my Hand upon the Machine, but ceased upon taking it off. This at once proved to me, that the electrical Fire passed from the Floor thro' my Body to the Machine. I then order'd the Man to put one of his Feet from the Wax upon the Floor; which, as soon as he complied with, caused the Electricity to snap at the Gun-barrel, and this ceased upon his replacing his Foot. Here I found, that the electrical Power came through the Man; and that, in these Instances, either myself, or the Man who touched the Floor with his Foot, was to be regarded as an additional Part of the Machine communicating with the Floor. These Considerations led me to make the following Experiments.

48. If my Conjectures were well founded, and if the electrical Power, the Man and the Machine being placed upon Originally-electrics, went through my Body to the Machine, a fine Wire, held in my Hand at a few Inches Distance, ought to be attracted by any Part of the Machine. This succeeded accordingly, but the Attraction lasted a very small
Space

Space of Time, and the Wire again hung perpendicularly from my Finger, though the Globes continued in Motion. This induced me to believe, that the Gun-barrel, and the other Non-electrics suspended in Contact with the Globes, would only contain a certain Quantity of the electrical *Æther*; and if this were the Case, the Attraction of the Wire to the Machine would be continual, if the electrical Power found again a Communication with the Floor, as the Wire was the only Canal of Communication between the Floor and the Machine. Whereupon I placed one of my Fingers upon the Gun-barrel, and held a Wire near the Machine with my other Hand, and found, that as long as my Finger continued upon the Gun-barrel, the Wire was attracted, but no longer.

49. Here we find, that one Cause of the electrical Attraction is the Current of the electrical *Æther* setting to the Machine through the Wire; and this Current is stopped from two Causes; one, when there is no Discharge thereof from the Gun-barrel, the Accumulation being complete; the other, when other Currents are opened, that is, when the Machine is touched in other Parts.

50. In these, and the subsequent Experiments, I always suppose the Air very dry; for if it is not, and the silk Lines, which support the Non-electrics, are wetted thereby, the electrical Power will be discharged along them, and the Wire will be constantly attracted, as I have frequently on purpose experienced; and this Discharge is in proportion as the Lines are more or less wetted.

51. If a Man stands upon the Machine placed upon Originally-electrics, and the Gun-barrel with the other Non-electrics are suspended as usual in Contact with the Globes, no Electricity is observed in that Man: But if a Wire, hanging to the Wainscot of the Room, touches the Gun-barrel, or a Man standing upon the Floor applies his Finger thereto, the Man upon the Machine emits Fire copiously; and either himself, or the Man who turns the Wheel of the Machine, fires inflammable Substances. But this Effect is no longer observable, when the Wire, &c. are removed from touching the Gun-barrel. So that, in this Experiment, the usual Course of the Electricity is inverted; and that Power, which, in most other Instances, is brought by the Wood-work of the Machine to the Globes, and by them discharged upon the Gun-barrel, is now brought by the Wire to the Gun-barrel, and from this the Globes throw it all over, not only the Machine, but any Non-electric in Contact with it, if the Electricity is stopp'd. In this Experiment, if an iron Rod, standing upon the Floor, is inclined against the Loops of the silk Lines which support the Gun-barrel, in such a manner as not to touch the Gun-barrel, the electrical Fire, which passes from the iron Rod to the Gun-barrel, instead of being supplied constantly, comes in by snapping so long as any unexcited Non-electric communicates with the Machine, but ceases upon its being removed: And if the Air is very dry, and none of the Electricity conducted down the silk Lines, the Snapping from the iron Rod to the Gun-barrel will frequently correspond to the touching of the wooden Machine with
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your Fingers, and stop upon your taking them off. And this Experiment will look much like Magic, even to those who are acquainted with the Operations of Electricity; for if the Person who turns the Wheel of the Machine, and stands upon the Cakes, be properly instructed: upon your bidding the Gun-barrel snap, he only puts the Toe of his Shoe upon the Floor, and it snaps immediately, and continues snapping as long as he keeps it there; but if you order it to cease snapping, he almost imperceptibly replaces his Foot upon the Cakes, and it ceases. This may be repeated as often and as long as you please.

52. Many Experiments demonstrate, that if the Electricity is not stoppt, no Sign of its Presence, either by Fire or Attraction, is observable in the non electric Bodies suspended to the Globes: that is, although ever so great a Quantity be determined by the Globes over these Bodies, the Electricity passes off from them *pleno rivo* to the Floor, from whence it came: but if the Electricity is stoppt, it is then accumulated upon these Non-electrics; but this can be done only to a certain Degree, as is manifest from a former Experiment. And if, when this Power is accumulated, a Man standing upon the Floor touches now-and-then the Non-electrics with his Finger, the Electricity, which is here accumulated, snaps, and the Fire is always observable. But this Snapping is not, when the electrical Power passes off continually, as from a Piece of blunt Wire hung to the suspended Gun-barrel, and the Hand of a Man brought near it without touching; whereby the electrical Power becomes visible, like a fine

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blue

blue Cone of Flame, with its Point towards the Wire. When the Hand is placed at a proper Distance, the Blast, like that of cold Air, is therefrom very manifest. If you do not determine the Electricity by these means to a Point, the Dissipation of it is general, and from all Parts of the excited Non-electric; but if you do, by bringing your Hand near the Wire as before-mention'd, you see the Manner of its being discharged into the Floor, and so into the Earth. These Facts being so, if my Conceptions are true, that the glass Globes circulate the electrical Fire, which they receive from their Friction against the Cushions, or the Hand of a Man, and which is constantly supplied to these last from the Floor; the Ingress of the electrical Fire. if the Machine, &c. are placed upon Electrics *per se*, ought to be visible, as well as the Egress under the same Circumstances; and this is demonstrated by Experiment, For if, while any unexcited Non-electrics touch the Gun-barrel, the Globes being in Motion, you bring your Finger, or a Piece of Wire near any Part of the Wood-Work of the Machine, but more especially the iron Axis of the Wheel; you observe the Brush of blue Flame set in from it to the Wood-Work. We always observe, in this Experiment, that the lambent Flame from the End of the Wire passes diverging into the Machine, and this continues so long as the Gun-barrel is touch'd. So that here the Office of the Globes exactly tallies with that of the Heart in Animals; which, as long as the Quantity of Blood is supplied, propels it into the Arteries, and these all over the System; or that of the Pump in Hydrostatics. In the same manner,

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by the Attrition of glass Tubes, the electrical Power is brought from the Body of the Man who rubs the Tube ; and he is constantly taking in a Supply from the Floor.

53. What I here call the electrical *Æther*, is that Atmosphere which surrounds both excited Originally electrics, and excited Non-electrics. That this is extended to a considerable Distance, appears, from a fine Thread, or Piece of Cotton-grass Seed, being attracted at some Distance from them, as far as which, it is presumed, this Atmosphere extends. Here indeed it is only perceived by its Effects upon these light Substances : but at the Brush of Flame from the End of the Wire before-mention'd, from some Bran lying upon a flat Piece of Metal in Contact with excited Non-electrics, your Hand being held over it, and in many other Experiments, it becomes manifest to your Feeling as a Blast of cold Wind. You feel it likewise in a less Degree, when a glass Tube is well excited, and brought near your Face. If no unexcited Non-electric is near, this Atmosphere seems to be determined equally over all the excited Non-electrics in Contact with the Machine ; but if a Non-electric unexcited is brought near, the greatest Part of it is determin'd that way ; and hereby the Attraction at any other Part of these excited Non-electrics is considerably diminished. Hence the Cause of the Repulsion of Electricity, which does not operate, until the electrical *Æther* is sufficiently accumulated. This electrical Repulsion is strongest in those Parts of the excited Non-electrics, where unexcited Non-electrics are brought near them ; for by these the electrical Blast, which

otherwise is general, is particularly determined to the Floor.

54. Before I proceed further, I must beg Leave to explain what I call the Accumulation of Electricity. To put a similar Case: As we take it for granted, that there is always a determinate Quantity of Atmosphere surrounding the terraqueous Globe, we conceive, when we see the Mercury in the Barometer very low, that there then is a less accumulated Column of this Atmosphere impending over us, than when we see the Mercury high. In like manner when we observe that the electrified Gun-barrel attracts or repels only very light Substances at a very small Distance, or that the Snap and Fire therefrom are scarcely perceptible; we conceive then a much less Quantity of electrical Atmosphere surrounding the Gun-barrel. This Power being more or less, we call the greater or less Degree of the Accumulation of Electricity. This is only attainable to a certain Point, if you electrify ever so long; after which, unless otherwise directed, the Dissipation thereof is general. The Phial of Water of *Muschenbroek* seems capable of a greater Degree of Accumulation of Electricity, than any thing we are at present acquainted with: And we see, when, by holding the Wire thereof to the Globe in Motion, the Accumulation being complete, that the Surcharge runs off from the Point of the Wire, as a Brush of blue Flame. A Method has been discovered here by a Gentleman (Mr. *Canton*) by which the Quantity of accumulated Electricity may be measured to great Exactness. The Manner of measuring is this: When the Phial is sufficiently electrified by applying

applying the Wire thereof to the glass Globe, and which is known by the Appearance of the Brush of Flame at the End of the Wire, as before-mention'd; hang a slender Piece of Wire to the suspended Gun-barrel for this Purpose detached from the Globes. Upon your applying the Wire of the electrified Phial to that hanging to the Gun-barrel, you perceive a small Snap; this you discharge by touching the Gun-barrel with your Finger, which likewise snaps: And thus alternately electrifying and discharging, you proceed until the whole Electricity of the Water is dissipated; which sometimes is not done, under an hundred Discharges. If you do not discharge the Electricity every time, the Snaps from the Wire of the electrified Phial to the Gun-barrel are scarcely perceptible. In proportion to the Number of Strokes, you estimate the Quantity of the acquired Electricity of the Water. That you could, by stopping the Electricity, excite Non-electrics; and, by accumulating their Power, make them exert more Force than Originally-electrics would at any Point of Time, was that capital Discovery of the late Mr. *Gray*; and is to be regarded as the Basis, upon which all the present Improvements of our Knowledge in Electricity are founded; and till which Discovery, although some of the Effects of Electricity were observed above two thousand Years ago *, little Progress was made.

55.

* *Theophrastus*, who lived above three hundred Years before the Date of the Christian Æra, takes Notice of Amber and the *Lyncurium*,

55. The electrical *Æther* is much more subtil than common Air, and passes to a certain Depth through all known Bodies. It passes most readily through Metals, Water, and all Fluids, except resinous ones; then animal Bodies dead or alive, in proportion as they are more or less wet; then Stones, Wood, and Earths. It passes to a certain Thickness only thro' Resins, dry animal Substances, Wax, and Glafs. For this Reason Bodies are called Electrics *per se*, or Non-electrics; not only for their rubbing the Electricity from other Bodies, but likewise as they permit more or less of the electrical *Æther* to pass through them. This *Æther* has not only the Property with Air of moving light Substances; but it seems to have another, and that is Elasticity.

56. That this Fluid is more subtil than common Air, is more particularly demonstrated by its passing through several Glafs at the same time; through any one of which, though ever so thin, Air cannot pass. It likewise passes, as I have mention'd before, through all known Bodies, except Originally-electrics, and even through these to a certain Degree. Its Elasticity is proved by its extending itself round excited Electrics, and excited Non electrics, to a considerable Distance; as well as by its increasing the Motion of Fluids. This is demonstrated by the Experiment with a small glass Siphon where the

curium attracting not only Straws, and Shavings of Wood, but also thin Pieces of Copper and Iron. See *Theophrastus* περί των λίθων &c.

—Και τὸ λυσιμύειον — ἔλαει γὰρ ὡς περ τὸ ἡλεκτρον. Οἱ δὲ φασιν ἔμεινον κάρφῃ καὶ ξύλῳ, ἀλλὰ χαλκὸν καὶ σιδήρον, εὖν ἢ λεπτόν. ὡς περ καὶ Διοκλῆς ἔλεγγον. See p. 74. in the late Edit. by J. Hill.

the Elasticity of the electrical *Æther* overcomes the Attraction of Cohesion: I have frequently observed this Experiment does not operate, unless the greatest Part, if not the whole electrical Blast, is determined to the Floor through the Water, by bringing some unexcited Non-electric near the long Leg of the Siphon †. The Stream through this slender Tube is most complete, when the Non-electric is brought near, so as when the Room is somewhat darkened, the Stream of Water appears as a Stream of blue Flame, much like that from the blunt Wire. This Stream is stopped, either by touching any Part of the Non-electrics in Contact with the Globes; by placing the Machine and the Man who turns the Wheel upon Electrics *per se*, by which the Current of the electrical *Æther* from the Floor to the Machine is prevented; or by removing the Non-electric from the Leg of the Siphon, by which the Dissipation of the electrical *Æther* from the excited Non-electric becomes general. So that we find, that although we can repel light Bodies from many Parts of excited Non-electrics at the same time; the whole Force of the electrical Current is necessary, to drive off

† There is one Instance, where the Water will run off in a full Stream without bringing a non-electric unexcited near the long Leg of the Siphon; and that is, by suspending a Phial of Water, as usual to the Gun-barrel by a Wire, and by letting a glass Siphon through the Cork into the Water. When this Phial is sufficiently electrified, the Water therein runs off in a full Stream, though no Non-electric unexcited is near; because then the Current of Water through the Siphon is the only Way, by which the Surcharge of the Electricity can be dissipated.

off so ponderous a Fluid as Water. May we likewise not infer the Elasticity of electrical *Æther*, from the Ingress of the blue Flame from the End of a blunt Wire held near the Axis of the Wheel, or any Part of the Wood-work of the Machine, after the Revolutions of the Globes are ceased? Certainly we see an Influx of electrical Fire to all Bodies, until their determined Quantity is restored. Is not the Elasticity of this *Æther* deducible likewise from the violent Shock we feel in our Bodies in the Experiments with Water?

57. There seems to be a Quantity of this *Æther* in all Bodies. Hence the Reason why, though the Machine is placed upon Electrics *per se*, a Snap or two, as I mention'd before, is observ'd upon touching the Gun-barrel, when the Machine has been some time in Motion: But after these no more is perceiv'd, if the silk Lines are very dry, and the electrical Supporters of the Machine are of a requisite Thickness. As soon as any Non-electric unexcited touches the Machine, this Loss is immediately restored. As the electrical *Æther*, as has been specified, is an elastic Fluid, wherever there is an Accumulation thereof, there is an Endeavour by the nearest unexcited Non-electric to restore the *Æquilibrium*. The restoring of this *Æquilibrium* I take to be the Cause of the Attraction of excited glass Tubes and Globes, as well as that of excited Non-electrics; for here the Blast of electrical *Æther* constantly sets in from the nearest unexcited Non-electrics towards those excited, and carries with it whatever light Bodies lie in its Course. This setting in
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of the Current of electrical Æther towards excited Non-electrics is likewise very perceptible to your Feeling as a Blast of cold Wind ; if when you are electrified, you hold your Hand over a Plate with some Bran in it, by which Blast the Bran is carried against your Hand. These light Substances are again repell'd by the Blast from the excited Bodies, as soon as they come in Contact, and sometimes before. The Successions of these alternate Attractions and Repulsions are extremely quick, so that sometimes your Eye can hardly keep Pace with them. And if you put a glass Globe of about an Inch in Diameter very light and finely blown into a Plate of Metal, and hang another Plate over it ; electrify the upper one, and bring the other under it, and you will find the Strokes from the alternate Attractions and Repulsions * almost too quick for your Ear. I have seen a *German*, who travell'd with a small electrifying Machine, who, by a Process of this sort, made two small Bells ring. One of the Bells was suspended to an electrified Wire, which was conducted without touching along the Sides of the Room ; at about an Inch Distance, detached from this Wire, a little Clapper was hung by a silk Line ; at an equal Distance from this last was hung another little Bell, which communicated with the Sides of the Room.

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* The following is an Argument of the Velocity likewise, with which these little Globes are attracted and repell'd. If they are let fall from the Height of six Feet or more upon a wooden Floor, or a Plate of Metal, they are rarely broke ; but by the Attractions and Repulsions of them between the Plates, though at the Distance only of one sixth of an Inch, they are frequently beat in Pieces.

As soon as the Machine was in Motion, the electrified Bell, attracted the Clapper, which immediately by the repulsive Blast was blown off to the unexcited Bell. By the time the second Bell was struck, the former attracted again; and this Jingling of the two Bells continued not only during the Motion of the Machine, but several Seconds after it was stopped. This was occasioned by the small Volume of the Clapper being able to convey away only a small Quantity of the electrical *Æther* at each Stroke; by which it was some time before the *Equilibrium* was restored.

§8. To demonstrate likewise, that the restoring this *Equilibrium* is not imaginary, I shall mention an Experiment of a Gentleman (Mr. *Wilson*) who has taken great Pains in these Inquiries. Take two Plates of any Metal, very clean and dry, whose Surfaces are nearly equal; hang one of them to any excited Non-electric, and bring under it upon the other a whole Leaf of Silver. When, which you find upon Application, the silver Leaf is attracted, lower the bottom Plate; if it is too low, you will observe the leaf Silver jump up and down; if too high, it will only be attracted in Part, and thereby dissipate the electrical Power. But if you get it at the proper Distance, which will very easily be found upon Trial, the Silver will be perfectly suspended at right Angles with their Planes, like the *Trapezium* of the Geometers, and touch neither of the Plates; it will be extended likewise to its utmost Dimensions. You frequently observe, both at the Top and Bottom of the Silver, the electrical Fire. The same Effect is produced, if you reverse the Experiment,

ment, by electrifying the bottom Plate, and suspending the other over it. Now I conceive, that the Space occupied by this Leaf of Silver, is that where the *Æquilibrium* of the electrical *Æther* is restored; for if you take away the under Plate, thro' which from the Floor the Flux of this *Æther* is furnished, or if that Plate be placed upon an Electric *per se*, by which this Flux is prevented likewise, the silver Leaf is blown away.

59. No Body can be suspended in *Æquilibrio* but from the joint Action of two different Directions of Power: So here, the Blast of electrical *Æther* from the excited Plate blows the Silver towards the Plate unexcited. This last, in its Turn, by the Blast of electrical *Æther* from the Floor setting through it, drives the Silver towards the Plate electrified. We find from hence likewise, that the Draught of electrical *Æther* from the Floor, is always in proportion to the Quantity thrown by the Globes over the Gun-barrel; or the *Æquilibrium* by which the Silver is suspended, could not be maintained. I once found, that a Gentleman, at that time an Invalid, whose Shoes were perfectly dry, and of consequence Originally-electrics, and who was employ'd to hold the Non-electric Plate through which the *Æther* was to come from the Floor; this Gentleman, I say, did not furnish a sufficient Quantity, because of the Dryness of his Shoes, to maintain the *Æquilibrium*; and the Silver was blown away. But upon employing another to this Office, whose Shoes were more wet, the *Æther* came readily through him, and the Silver was suspended. I have likewise found a wooden Pole, very dry, not

conduct this *Æther* fast enough to keep the Silver suspended. It may be imagined, that it is possible for the Silver to be suspended, without supposing a Flux of the electrical *Æther* from the nearest unexcited Non-electric, as well as from the excited one; that is, by the simple electrical Attraction. But to obviate this, it must be remembered, that the electrified Gun-barrel both attracts and repels light Substances at the same time. Can this Attraction and Repulsion be conceived without the Operation of the electrical *Æther* both to and from the Gun-barrel at the same time? Does not this point out an Afflux as well as an Efflux? Are not the electrical Repulsions as strong at least as the Attractions? Do not we see light Bodies, either between excited Originally-electrics, or excited Non-electrics, and unexcited Non-electrics, dart like a Ball between two Rackets of equal Force? It may be said perhaps,

1. That the suspended Silver may only serve as a Canal of Communication, which discharges the Electricity from the excited Non-electric to the unexcited one; and that when an Originally-electric is placed between the lower Plate in this Experiment and the Floor of the Room, that then the Silver is attracted only, until the lower Plate is saturated with Electricity, and no longer. This is as much as saying that this Effect arises from Electricity, without mentioning in what manner.

2. That this Effect is produced by the electrical Attraction, which gives the Silver a Direction towards the excited Non electric, but that it is kept down near the unexcited one by the Force of Gravity.

vity. Was this the Cause, the Action of Gravity would operate as much thro' Originally-electrics as through Non-electrics.

60. But I am able to prove the Afflux experimentally, as well as the Efflux, in the following manner. When the Silver lies still, though the Motion of the Globes is continued between the two Plates, one suspended to the Gun-barrel, and the other placed upon an electrical Cake, a Person standing upon the Floor needs only bring a small glass Siphon in a Vessel of Water, and apply the long Leg thereof near the Plate placed upon the Wax; for upon this the Silver is immediately suspended; and the Water, which before only dropp'd, now runs in a full Stream, and appears luminous*. Does not, in this Case, the Current of the Water point out the Direction of the Current of electrical Æther?

61. When the Machine, &c. are placed upon Originally-electrics, if a Man, standing likewise upon an Originally-electric, touches the Gun-barrel while the Globes are in Motion, he will receive a Snap or two; after which, though the Motion of the Globe is continued, he will perceive no more Fire from the Gun-barrel. While in this Posture,

* This Experiment is more elegant, if the upper Plate, attracting the Silver, is suspended high enough for a Person standing upon an Originally-electric, conveniently to bring the other Plate under it with one Hand, and to hold a pewter Plate in the other. If the Originally-electric is sufficiently thick, the Silver will not be suspended; but if the glass Siphon in a small Vessel of Water is brought very near the pewter Plate, the Water runs into the Plate, and the Silver is immediatly suspended.

Posture, if he touches the Wood-work of the Machine with one Hand, and applies a Finger of his other near the Gun-barrel, at that Instant he receives the electrical Strokes. These continue as long as he touches the Machine, but cease upon his removing his Hand therefrom. Here we see a Circulation of Part of this Man's electrical Fire, which operates in the following manner. First; The Man, by applying one of his Hands to the Machine, becomes a Part thereof; and, by the Motion of the Globes, Part of the electrical Fire, inherent in his Body, is driven upon the Gun-barrel; but it is instantaneously restored to him again, upon his touching the Gun-barrel with his other Hand. Thus he continues communicating the Fire with one Hand, and having it restored to him with the other, as long as he pleases. If, instead of touching the Machine or Gun-barrel, he holds his Finger near either or both of them, you see the Fire go out, and return back, as in a former Experiment.

62. It may be perhaps imagin'd, if one Man touches the Machine, himself and the Machine both being placed upon the Wax, and if another, standing upon the Floor, constantly, or by turns, touches the Gun-barrel, that by these means the Man upon the Originally-electrics might be divested of all his electrical Fire, by constantly continuing the Motion of the Globes, as he receives then no Supply from the Floor. But the contrary proves true; and, after a considerable time, the Strokes from the Gun-barrel are as strong as at first. But here we must observe, that the Gun-barrel suspended will not contain probably at one time a thousandth Part of the whole Quantity of this
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this Man's electrical Fire: Therefore I conceive, that, as soon as this Man has parted with any Portion of his necessary, his determined Quantity, to the Gun-barrel by the Motion of the Globes, he has it restored to him upon any un-excited Non-electric's touching the Gun-barrel, by having the usual Course of the Electricity * inverted.

63. We see, from many Experiments, that dry Wood does not conduct Electricity so well as that which is wet; and that the Man standing upon the Floor, who rubs the Globes, excites the Electricity stronger than the Cushions. This I had Reason to conceive was owing not to any other Difference, than that of his being more moist, and, of Consequence, more readily conducting the Electricity from the Floor. Therefore I order'd my Machine, and even the Cushions to be made damp, by causing wet Cloths to be placed upon several Parts thereof; and found then, that the Electricity was equally strong, as when the Globe was rubbed by the Hand.

64. It remains now, that I endeavour to lay before you a Solution why our Bodies are so shocked in the Experiments with the electrified Water; the Difficulty thereof I confess seemed unsurmountable, until I had made the following Discoveries.

1. That the Electricity always described a Circuit between the electrified Water and the Gun-barrel.

2. That the electrical Fire came from the Floor of the Room.

3. That it would not pass from the Floor quick enough for the Person to be shook, if his Shoes were dry.

4.

* For a further Account of this Matter, see *Philos. Transact.* Vol. XLV. p. 101.

4. That the Force was increased in proportion to the Points of Contact of Non-electrics with the Glafs containing the Water.

Then the Solution of this Phænomenon became more easy, which I take the Liberty to offer.

1. I have endeavoured to prove by Experiment*, that a Quantity of Electricity is furnish'd from the nearest unexcited Non-electrics, equal to that accumulated in excited Originally-electrics and excited Non-electrics.

2. This being so, when the Phial of Water held in one Hand of a Man is highly electrified, and he touches the Gun-barrel with a Finger of his other; upon the Explosion which arises herefrom, this Man instantaneously parts with as much of the Fire from his Body, as was accumulated in the Water and Gun-barrel; and he feels the Effects in both Arms, from the Fire of his Body rushing through one Arm to the Gun-barrel, and from the other to the Phial. For the same Reasons, if, in the Experiment with the electrical § Mine, a Man places his right Foot upon the lower small Wire, and touches the Gun-barrel with his left Arm, the electrical Force is only felt in that Leg and Arm.

3. As much Fire as this Man then parted with, is instantaneously replaced from the * Floor of the Room, and that with a Violence equal to the Manner in which he lost it. To confirm this, see *Exp.* 54.

4. But

* Sect. 56, 57, 58.

† Sect. 60.

* See more of this in *Phil. Transf.* Vol. XLV. p. 102.

4. But this Flux of electrical *Æther*, either from the Floor to the Man, or from the Man to the Water, is prevented for Reasons sufficiently obvious, if the Glass containing the Water be thick; if the Points of non-electric Contact are few; if the Man is placed upon Originally-electrics; or (which is the same thing) if the Soles of his Shoes are dry.

5. As we find that the Electricity passes at least equally quick through dense Mediums, which are Non-electrics, as through those which are more lax and spongy; may we not therefore conclude, that the Cause why we feel most Pain at the Joints of our Arms, and in the Tendons of our Heels†, arises from the Texture in the Tendons and tendinous Ligaments of those Parts?

65. From a due Consideration of the *Phænomena* before us, I take the Liberty of proposing the following Queries:

1. Whether or no the Effects we observe, in Bodies being drawn to and driven from either excited Originally-electrics, or excited Non-electrics, are to be attributed to the Flux of electrical *Æther*?

2.

† This Pain in the Heels is felt only in the Experiment with the electrical Mine; and it is not perceptible only when you touch the lower small Wire with your Foot, but likewise if you stand upon Non-electrics, which touch this Wire. It has been strongly felt by a Person standing upon a Pedestal of *Portland Stone* near ten Inches in Height, and upon one of Metal more than two Feet. I am of Opinion, that no Mass of Metal, of Dimensions however great, would in the least prevent the Progress of the electrical Power from the Water in the Phials to the Body of the Man.

2. Whether or no, that, which, from its being first discover'd in Amber, we call Electricity, electrical Æther, electrical Power, &c. is any other than elementary Fire?

3. Whether or no this Fire does not appear in different Forms, according to its different Modifications? Does it not, when diffused under a large Surface, appear to affect us as Air? When brought towards a Point, does it not become visible, as lam-bent Flame? When nearer still, does it not explode, and become the Object also of our Feeling as well as of our Hearing? Altho' it does not affect our Skin with the Sensation of Heat; does it not, by its lighting up inflammable Substances, shew itself to be truly Fire?

4. Whether or no this Fire is not connected intimately with all Bodies at all times, though least of all, probably, with pure dry Air? Have we not found and separated it from Water, Flame, even that intense one of Oil of Turpentine, Smoke, red-hot Iron, and from a Mixture thirty Degrees colder than the freezing Point?

5. Have we not proved its Subtility, from its passing through all known Bodies?

6. May we not infer its Elasticity likewise from its Explosions, from its increasing the Motion of Fluids, as well as from its Effect in the Concussion of our Bodies, when we discharge it after we have accumulated it in Water?

7. May not the electrical Machine, from its Uses, be denominated a Fire-Pump, with equal Propriety as the Instrument of *Otto Guericke* and Mr. *Boyle*, that of the Air?

8. Does not the Power we are now Masters of, of seeing the Separation of Fire from Bodies by Motion §, and of seeing it restored to them again, and even after that Motion has ceased, cause us rather to incline to the Opinions of *Homberg* (a), *Lemery* the younger (b), *s'Gravesand* (c), and *Boerhaave*,

§ The setting in of the Fire to the glass Tubes and Globes has always, in these Experiments, been visible both from the Hands and Cushions, by which they were rubbed. But as, till now, this Fire was considered as coming from the Glass, that, observed upon the Hands and Cushions, was always believed to be so much lost by running down the Instruments of Friction into the Floor. I endeavoured to prevent this Loss, by standing upon Originally-electrics; and found, to my great Surprise, that so far from increasing the electrical Power, by stopping what I conjectured was so much Loss, I could excite then no Electricity at all in the Tube and Globes. This Disappointment, which, I afterwards found, had occurred to Mess. *Bose* and *Allamand*, was the Foundation of my discovering the Source of the Electricity, and the Manner of its Ingress to the Machine.

(a) *Homberg* du souphre principe. *Mem. de l'Acad. Royale des Sciences*, 1705. La matière de la lumière est la plus petite de toutes matières sensibles — elle passe librement au travers et par les pores de tous les corps, que nous connoissons. — Que tout l'univers est rempli de la matière de la lumière — J'ai mieux donné à notre souphre principe le nom de matière de la lumière, que celle du feu, quoique ce soit proprement la même chose.

(b) *Lemery* le fils. *Mem. de l'Acad.* 1709. p. 527. La matière de feu doit être regardée, comme un fluide d'une certaine nature, et qui a des propriétés particulières, qui le distinguent de tout autre fluide. Pag. 8. — Qu'une matière beaucoup plus subtile et plus agitée, qui remplit tous les vuides de l'univers, et ne trouve point les pores si étroits, qui ne lui laissent un libre passage, coule incessamment dans les lieux où elle est enfermée, et entretient son mouvement.

(c) *s'Gravesand Philosoph.* *Newton institutiones*, cap. 1. Ignis in corpora omnia quantumvis densa et dura penetrat. — Corporibus

Boerhaave (*d*), who held Fire to be an Original, a distinct Principle, formed by the Creator himself, than to those of our illustrious Countrymen, *Bacon* (*e*), *Boyle* (*f*), and *Newton* (*g*), who conceived it to be mechanically producible from other Bodies?

9. Must we not be very cautious, how we connect the elementary Fire, which we see issue from a Man, with the vital Flame and *Calidum innatum* of the Ancients; when we find, that as much of this Fire is producible from a dead Animal as a living one, if both are equally replete with Fluids?

10. Whether or no it is not highly probable, that, by increasing the Number and Size of the Phials of Water in a certain manner, you might not instantly

ribus sese jungit — ignem ad certam distantiam a corporibus attrahi — nulla novimus, quæ ignem non continent — non ignis æque facile corpora omnia intrat — corporibus contentus in his a corporibus circumambientibus retinetur. — Motu celerrimo ignem affici posse.

(*d*) *Boerhaavii Elementa Chem. de igne*, p. 187. et seq. — Ipse ignis — semper præsens existit in omni loco — imo vero in omni corpore, etiam rarissimo, vel solidissimo, æqualiter distributus hæret. — Haud ergo potui detegere, quod in rerum natura sit vel ullum spatium sine igne.

Ibid. p. 283. Huc usque conabar — tradere ea, quæ verissima addiscere potui de natura illius ignis, quem elementalem appellant philosophi. Illum scilicet, ita considerando, prout creatus ipse in rerum (natura) existet seorsum, extra reliqua omnia creata, quæcunque demum sint, corpora.

(*e*) Vide tractatum *De forma calidi*.

(*f*) *Mechanical Origin of Heat and Cold*, Sect. 2.

(*g*) See Queries at the End of his *Optics*.

instantly kill even large Animals by the electrical Strokes (*b*) ?

66. I cannot conclude these Papers, without congratulating that excellent Philosopher and learned Member of this Society the Abbé *Nollet* of *Paris*. This Gentleman, almost two Years since, in a Letter to Professor *Bose* (an Extract of which this last published with a Work (*i*) of his own) without the Knowledge of several Experiments since discover'd; at least none of his Discoveries have yet fallen into my Hands, did declare his Opinion, (*k*) that the Electricity did not only proceed from the electrified Bodies, but from all others about them to a certain Distance; (*l*) that the Electricity, as well from Bodies electrified, as from those which were not, passed more readily through dense Mediums than Air; (*m*) that the Electricity is present in all Bodies; that

(*b*) Monf. *Le Monnier* at *Paris* killed Birds by these; and with me, a Linnet and a Rat, much more than half-grown (the largest I was then able to procure) have been struck dead.

(*i*) *Recherches sur la Cause, et sur la véritable Theorie de l'Electricité*. Wittembergue, 1745.

(*k*) *Voyez Nollet dans les Recherches, &c. du M. Bose*, Pag. xlv.—La matière électrique vient non seulement du corps électrisé, mais aussi de tous ceux qui sont autour de lui, jusques à une certaine distance.

Ibid. p. xlix. — Si vous pouvez vous convaincre comme moi, que la matière qui va au corps électrique vient primitivement de tous le corps environnans, de l'air même, vous aurez bien plus de facilité à expliquer tous les autres effets.

(*l*) *Ibid.* p. xlv. La matière électrique, tant celle qui sort du corps électrisé, que celle qui vient des environs à ce même corps, se meut plus facilement dans les corps dense que dans l'air même.

(*n*) *Ibid.* p. xlvii.

(n) that this Matter always tends to an *Æquilibrium*, and endeavours to occupy those Spaces in Bodies, which have not their necessary Quantity : All which Assertions may now be proved by Experiments.

67. You see, Gentlemen, by my asserting, that what we have hitherto called electrical *Effluvia*, do not proceed from the Glass, or other Electrics *per se*, I differ from *Cabeus, Digby, Gassendus, Brown, Des Cartes*, and very great Names of the last as well as the present Age. My differing from them would be Presumption indeed, were I not induced thereto, by Observations drawn from a Series of Experiments carefully conducted, to which many of you have been Witnesses, and to whom I may therefore appeal, for taking what may seem so extraordinary a Step. I have constantly had in View that excellent Maxim of Sir *Isaac Newton* laid down in his *Optics*, that, “ as in Mathematics, so in Natural Philosophy, the
 “ Investigation of difficult Things by the Method of
 “ Analysis ought ever to precede the Method of Com-
 “ position. This Analysis consists in making Experi-
 “ ments and Observations, and in drawing general
 “ Conclusions from them by Induction, and admitting
 “ of no Objections against the Conclusions, but such
 “ as are taken from Experiments, or other certain
 “ Truths. For Hypotheses are not to be regarded
 “ in Experimental Philosophy. And although the
 “ arguing from Experiments and Observations by
 “ Induction

(n) *La meme.* Cette matière tend à l'équilibre, et s'empresse de remplir les espaces, qui se trouvent vuides des parties de son espece.

“ Induction be no Demonstration of general Con-
 “ clusions; yet it is the best Way of arguing which
 “ the Nature of Things admits of, and may be
 “ look’d upon as so much the stronger, by how
 “ much the Induction is more general. — By this
 “ Way of Analysis we may proceed from Com-
 “ pounds to Ingredients, and from Motions to the
 “ Forces producing them; and, in general, from
 “ Effects to their Causes, and from particular Causes
 “ to more general ones, till the Argument ends in
 “ the most general.” I am desirous, that what is
 contain’d in these Papers, you will be pleas’d to re-
 gard rather as the rude Outlines of a System, than
 as a System itself; which, I am in Hopes, Men of
 better Heads and more Leisure will prosecute: And
 if hereafter, from being possess’d of more Observa-
 tions than we at present are Masters of, any Opi-
 nions in these Papers shall be found erroneus, I at
 all times shall be willing readily to retract them. I
 rely upon your wonted Candour, and am,

With the greatest Truth,

Oct. 20.
 1746.

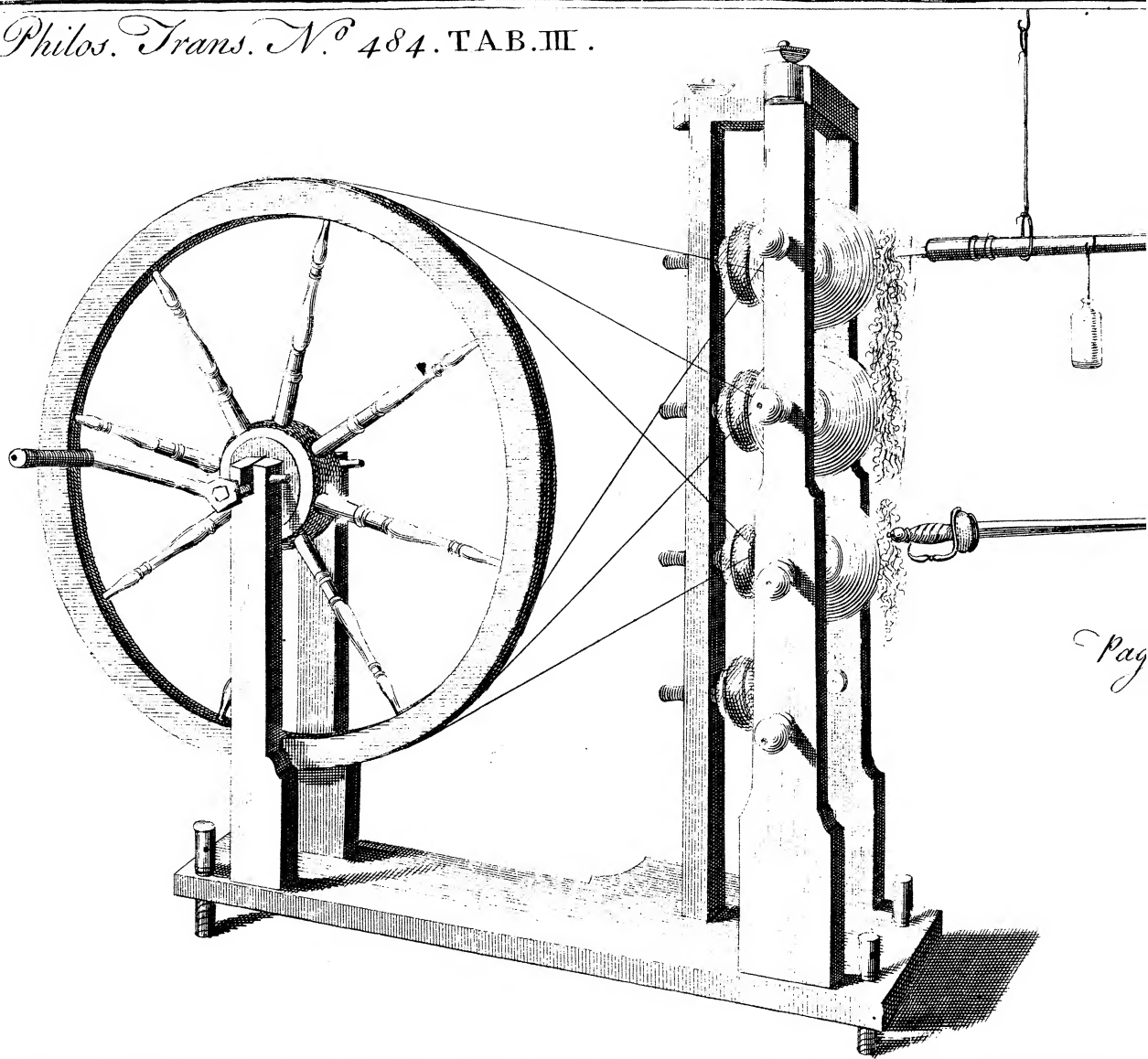
Gentlemen,

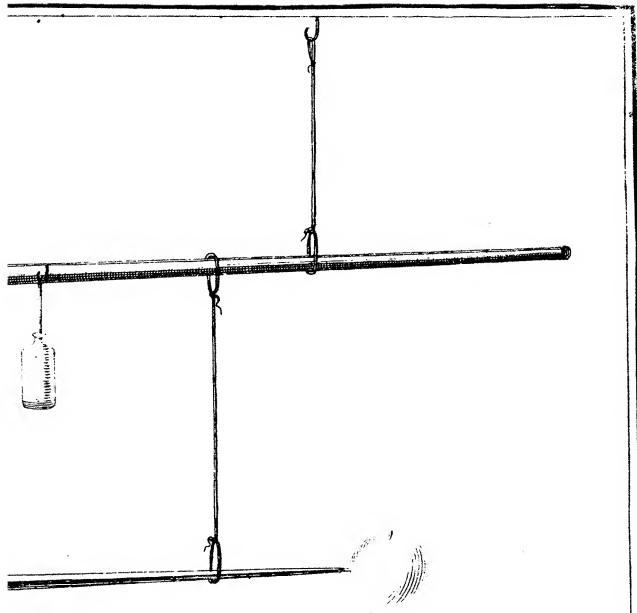
*Your most devoted
 and most humble Servant,*

W. Watson.

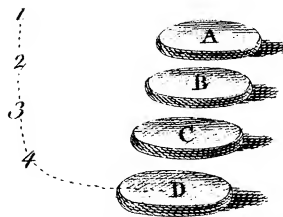
F I N I S.

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J. Mynde Sculp

Photo. Trans. V^o 12 p. 126-127.



Fig. 1st. Fig. 2nd.

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